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## MINIMISING LOGISTIC SUPPORT COSTS

### MODELLING TECHNIQUES IN THE ROYAL AIR FORCE

<p>Presented by: Mr F Boydell          Head of Logistic Support Costing          Block A          Royal Air Force Wyton          Huntingdon          Cambs PE17 2EA          England</p>	<p>Any views expressed are those of the author and do not necessarily represent those of the Agency.</p>
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#### INTRODUCTION

In all MOD procurement programmes, LCC is a prime metric in the selection process. The single biggest portion of a weapons system's LCC is the Logistic Support Cost (LSC). This paper will address the major considerations, models and analytical methods currently employed by the RAF to achieve maximum aircraft operational capability for the minimum LSC and analytical effort. The paper is broken into 2 distinct areas: introduction to service and through life support.

#### INTRODUCTION TO SERVICE

##### TEAMING FOR LSA

The RAF recognises those aircraft manufacturers and operators have, by necessity, very different skill sets and experience. Manufacturers' expertise lies in the design, development and manufacture of aircraft, but they have little or no experience of operating and supporting them. The RAF, by comparison, have precisely the opposite skill sets. The advantages of manufacturer/operator teaming are obvious; the manufacturer gets an extra team working alongside for free and the RAF get a better product. Consequently, the RAF has Project Teams based at the manufacturer's site for all major programmes. However, despite the clear win/win advantages of teaming, some manufacturers still resist any form of integration.

##### THE ANALYSIS PROCESS

The development of a joint manufacturer/customer LSA process is complex and needs to address: areas of responsibility, provision of data, data interchange, data and modelling review processes, as well as the models and methods for conducting LORA, Initial Provisioning (IP) and sustainability modelling.

##### LORA

LORA Screening. The first area of analysis that the RAF gets involved in, is how and where a system should be maintained and repaired. This is the objective of Level Of Repair Analysis (LORA). LORA is a manpower intensive and very costly process requiring the generation of large amount of data. A typical aircraft will contain around 3000 – 4000 repairable items to module level and each data set requires around 40 data elements. To carry out analysis

on all repairable systems regardless, would be financially irresponsible and very time consuming. Consequently, the first step is to screen out items with obvious Maintenance Policies (MPol). Typical criterion for screening would be:

##### System Already In-Service On Other Aircraft.

Providing we are not effecting a major change in the total fleet size for the system, we will usually adopt the existing MPol. This will still need an internal review of the existing stock of spares and available repair capacity. The use of an existing repair infrastructure and a common spares pool will have large potential savings.

Highly Reliable and Cheap Items. If the cost of establishing a repair infrastructure can clearly not be justified, the item will be scrapped on failure.

Strategic MPol. There may be operational reasons for imposing a particular MPol regardless of cost.

Specialist Facilities Required. If the item support requirements are beyond your capabilities, or require an unjustifiably large investment in new facilities, organic support will not be an option.

IPR Restrictions. Particularly when buying from the USA, IPR or transfer of technology restrictions will negate any organic support options.

This screening process can, depending on the aircraft type, reduce the items requiring LORA modelling to as few as 500 LRIs, greatly reducing the cost and time required and making huge savings on duplicate repair infrastructure and spares costs.

##### LORA MODELLING

Introduction. Simplistically, LORA compares the cost of pipeline spares against repair infrastructure. Figure-1 shows typical Repair Turn Round Times (TRTT) for RAF lines of maintenance.

Option 1: 1A-Scrap. The cheapest option might be to scrap the item on failure, for the reasons already discussed.

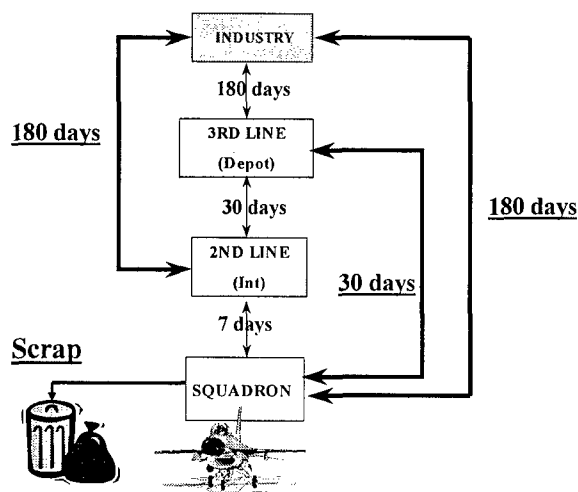


Figure-1: Repair Turnaround Times

**Option 2: 1A-4.** An alternative option might be to send items back to the manufacturer for repair. In this case we would require a large number of LRIs to fill the long pipeline, but no repair infrastructure. However, spares cost will be very high. Example 1 shows some theoretical costs that we can use for comparison with other Mpol.

FFR: 5760 Hrs per year      RTRT: 180 days  
Unit Cost: £10,000      Spares: 9.46 = 10  
MTBF: 300      Repair Costs: £1,000  
Arising: 19.2 = 20

COST	1A-4
Spares	£100,000
Test Equipment	
Manpower	
Publications	
Training	
4 <sup>th</sup> Line repairs	£20,000
Total	£120,000

Example 1: Costs of 1A-4 Mpol

**Option 3: 1A-2FB-4.** We need to consider other factors such as the No Fault Found (NFF) rate. If, as is not uncommon, an LRI has a NFF of 40%, the arisings in the above example rise to 28, our spares cost increase to £140,000 and our repair costs to £28,000. It may now be more cost effective to establish a Filter Bench at 2<sup>nd</sup> Line to prevent NFFs being sent back to the manufacturer. This would increase the pipeline times slightly for unserviceable items as shown below but - based on the figures used in Example 2 - reduce the annual support costs.

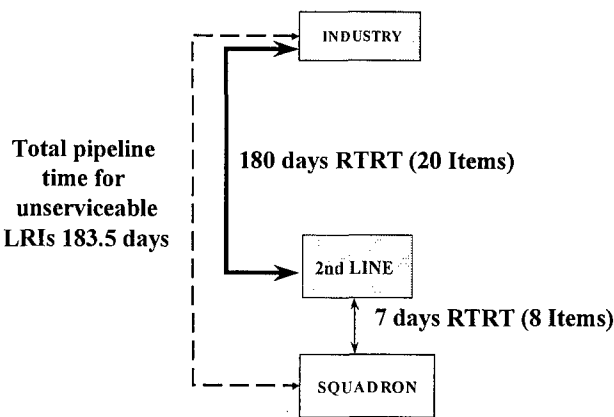


Figure-2: Modified RTRT For 1A-2FB-4 Mpol

AFFR: 5760 Hrs/year      4th Line RTRT: 183.5 days  
LRI Unit Cost: £10,000      4th line Spares : 9.46 = 10  
MTBF: 300 Hrs      2nd Line RTRT: 7 days  
Indicated Arisings: 28      2nd Line Spares: 0.82 = 1  
Time to Test: 1Hr      4th line Repair Costs: £1,000  
Manpower cost: £35 per hr      FB Test Set Cost £10,000

	1A-4 (NFF)	1A-2FB-4
LRI Spares Costs	£ 140,000	£ 110,000
Module Spares Costs		
2nd Line Manpower		£ 980
FB Test Set Cost		£ 10,000
Depth B Test Set Cost:		
AP Costs:		
Training Costs:		£ 1,000
LRI 4th Line Repair Cost:	£ 28,000	£ 20,000
TOTAL	£ 168,000	£ 141,980

Example-2: Costs For Filter Bench Option

**Option 4: 1A-2B-4.** The final example considers establishing a Depth B repair facility at 2<sup>nd</sup> Line. Now we need Depth B support equipment and spare modules, but fewer LRIs. The additional infrastructure costs are shown below.

AFFR: 5760 Hrs/year      Manpower cost: £35 per hr  
Indicated Arisings: 28      4th Line RTRT: 183.5 days  
LRI Unit Cost: 10,000      Modules Spares: 9.6 = 10  
LRI MTBF: 300 Hrs      2nd Line RTRT: 7 days  
Time to FB LRI: 1Hr      LRI Spares: 0.82 = 1  
LRI Repair Time 3 Hrs      Depth B Test Set Cost: £50,000  
Module Unit Cost: £2,250      Publications Costs: £5,000  
Module Repair Cost £300      Training Costs: £10,000

	1A-4(NFF)	1A-2FB-4	1A-2B-4
LRI Spares Costs	£ 140,000	£ 100,000	£ 10,000
Module Spares Costs			22500
2nd Line Manpower		£ 980	2380
FB Test Set Cost		£ 10,000	
Depth B Test Set Cost:			50000
AP Costs:			5000
Training Costs:		£ 1,000	10000
Module 4th Line Repair Cost			6000
LRI 4th Line Repair Cost:	£ 28,000	£ 20,000	
TOTAL	£ 168,000	£ 131,980	£ 105,880

Example-3: Costs For 1A-2B-4 Mpol

The table summarises the cost for all the examples. N.B. These are first year figures only. In subsequent years we do not need to buy spares and support equipment and hence the savings increase. Figure-3 shows the costs for all examples over a 10-year period.

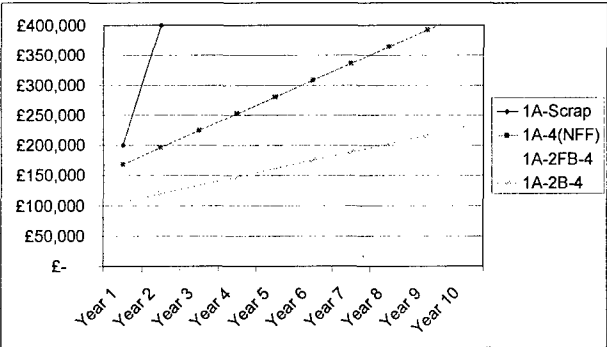


Figure-3: Cumulative Costs For 10 Years

These are of course only simplified examples. The true algorithms for LORA (defined in Mil Std 1390D) are far more complex, scaling spares against a chosen availability. Some models use single item scaling, whilst others optimise across the system. However, the scaling calculations in the LORA model are only used to determine the optimum MPol. Initial Provisioning of spares is carried out across the whole aircraft using specialist models as outlined below.

SPARES SCALING

Single Item Modelling. As we have seen in the LORA examples, the MPol drives the type of spares required. For scrapped or items returned directly to the manufacturer, only LRIs are required; whereas, any Depth B repairs will require modules. Spares are one of the largest cost elements within the LSC and consequently, the RAF has invested much of its development effort in a bid to minimise spares cost. For many years the RAF used Single Item Modelling (SIM) for both IP and Re-Provisioning (RP) of spares and indeed many manufacturers still use this method. SIM scales spares using a cumulative Poisson distribution for a given fill rate. What SIM

does not do is take account of the cost of an item; hence, an item costing £10,000 with the same reliability as another costing £1, would be scaled exactly the same, regardless of what improvement in system availability is achieved for each Pound spent. Further, simple Poisson distribution assumes demand rate equals arising rate which may not be so due to batching of demands.

Cost Optimised Scaling. Cost optimised scaling scales a whole range of items – even an entire aircraft – in a single analysis. The use of a Compound Poisson distribution caters for the probability of batched demands. To achieve a cost-effective scale for a range of components, effectiveness must be maximised with respect to cost. To achieve this, the RAF use a scaling model which uses the technique of Marginal Analysis (MA), also called a heuristic optimisation algorithm. To determine the value of incrementing a scale a Component Improvement Factor (CIF) must be calculated. This CIF can then be compared with CIFs for other components and hence, the best component to increment can be identified. The scaling model used by the RAF is OPUS 10. The output from OPUS is a series of scales (for all repairable components on the aircraft) that make up the OPUS curve. The curve allows us to select a scale that will provide a chosen availability and will cost that scale. Alternatively, it will indicate what availability can be achieved for a given cost. When compared with SIM, MA will achieve the same availability for 10%-15% less as shown in the diagram below. Benefits of OPUS are that it:

- Models the whole weapon system.
- Optimizes on cost and reliability or weight and reliability or volume and reliability.
- Provides a range of equipment scale options
- Recommends the optimum location for spares.
- Takes into account spares pipelines from forward operating bases to the manufacturer.

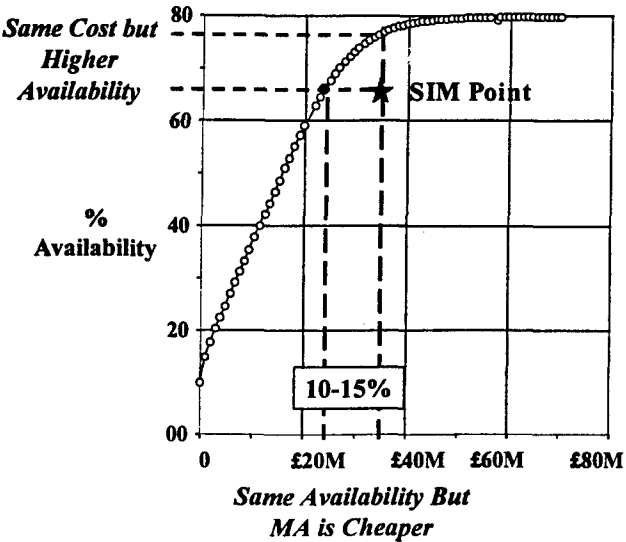


Figure-4: OPUS v SIM Comparison

## OPERATIONAL AVAILABILITY

The availability predicted by the OPUS model is that due to spares. However, aircraft availability will always be lower due to the need to re-arm, replenish and repair, as well as carrying out scheduled maintenance. Additionally, generating aircraft depends on availability of other resources such as Support Equipment (SE), maintenance technicians etc. All these will effect the Operational Availability (Ao). One limitation of the OPUS model is that it assumes that flying hours – and hence arisings - are accumulate linearly over the flying period rather than batched into irregularly spaced multi-aircraft sorties. To take account of all the above points and evaluate the effectiveness of the spares scale, the RAF use a bespoke simulation model – Operational Support Simulation (OpSSim). The model is particularly useful for validating scales for Priming Equipment Packs (PEPs) to support deployed operations. The scenario describing the support environment and how modelled resources interact with each other also needs to be defined.

A full day's, week's, month's or even year's flying scenario is entered as individual sorties with take off times, number of aircraft and sortie duration. Every sortie within the flying period can be different and we can choose how many days flying we wish to simulate. We can state which systems are mission critical and how many none-critical systems can fail before a sortie is aborted. Lastly we need to state the number of days between re-supply of spares.

Throughout the simulation OpSSim tracks how many aircraft are:

- On missions.
- Available for operations.
- In maintenance.

This allows us to check that we can achieve our mission targets, with the number of aircraft deployed and the PEP spares recommended by OPUS until the next re-supply date. Conversely, OpSSim ensures we do not procure or take more spares than are absolutely necessary. This reduces spares, transport and storage costs.

Outputs from OpSSim include:

- Mission success rate.
- Aircraft availability.
- Problem spares.

Where a spares pack is found to be inadequate, we can choose another scale of spares from higher up the OPUS curve and repeat the simulation process. This process allows the RAF to procure for a missions success rate rather than a meaningless spares availability figure.

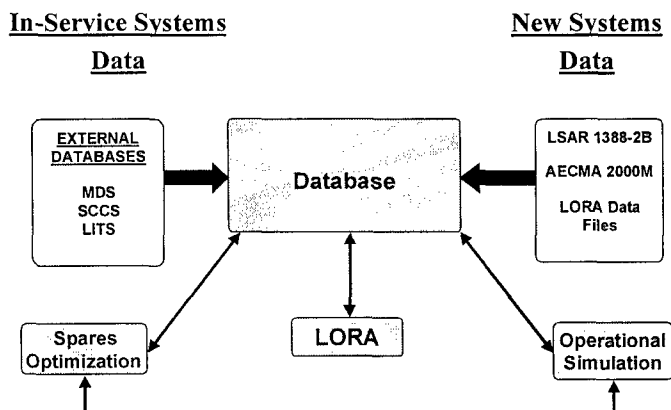
## THROUGH LIFE SUPPORT

Support analysis is never a once only exercise. The uncertainty of initial predicted equipment data, and changing operational, scenarios require regular re-analysis throughout the life of an aircraft. The addition of new aircraft to our modelling databases during procurement (updated throughout the aircraft's life) and the availability of an integrated modelling suite, simplifies iterative analyses and ensures that logistic support remains optimised throughout the life of the system. Our modelling suite, which uses a common source database to feed an integrated suite of models, allows rapid operational and cost analysis of proposed scenarios. A simplified representation of the suite is shown at Figure-5 below.

LORA Reviews. MPol reviews of in-service systems are carried out due to:

- Changing reliability.
- Changes in operational scenario.
- Changing fleet size.

However, in reality, it is rarely cost effective to change an MPol as the majority of the support infrastructure costs are already sunk.



**Figure-5: The RAF's Integrated Modelling Suite**

LORA Harmonisation. The demands for ever-greater savings are breaking down the logistics autonomy of the British Armed Services. LORA harmonisation is the process of defining a single MPol for common items used by several platforms; often across all three Armed Services. This can be applied to both legacy systems – such as avionics and aero-engines - with discrete support infrastructures. Defining and establishing a single repair infrastructure using a common spares pool can generate very significant savings in manpower, facilities and spares. Because we aim to make maximum use of sunken cost, the solution may well be sub-optimal when compared to a green field analysis.

Cost Benefits Analysis. The RAF receives many unsolicited bids from manufacturers for reliability or operational improvement modifications. Claims of massive costs savings invariably accompany these bids, but it is important that we investigate them independently before making any commitment. The initial phase of any Cost Benefits Analysis (CBA) is to determine the support cost for the remaining life of the current system, i.e. the 'do nothing' option. LORA tools and spreadsheets are a useful way of extrapolating these cost. The second phase is to carry out a full LCC of the proposed system. This will entail the use of our entire modelling suite to assess all initial and recurring costs. Occasionally, a relatively inexpensive modification will realise huge lifetime savings; a simple hydraulic coupling on the Tornado aircraft was just such an example. However, in the majority of cases, the modifications will never repay the capital investment within the remaining life of the aircraft.

*It is ironic that we save the MOD enormous amounts of money, by persuading them not to invest in cost saving measures.*

Scaling Reviews. As for LORA reviews; changing physical and operational factors, plus condemnation of items that become beyond repair, requires periodic scaling reviews to determine any deltas between current stock holdings and requirements. Because of poor procurement decisions made in the past, it is sometimes found that the actual spares holding for an aircraft may run to tens of millions of pounds, but give only a very poor Ao. This is because we have lots of the wrong spares. A recent study identified an aircraft with holdings of £80M that could achieve a better availability with a green field scale of only £25M. With the punitive fines imposed under resource accounting and budgeting rules, we found we could save circa £56M over the life of the aircraft by selling unwanted spares and buying (at a cost of £1.5M) the correct spares to align holdings to the green field scale.

Operational Sustainability. Much of the in-service analysis is for PEPs to support deployed operations. The OPUS/OpSSim combination allows for rapid assessment of spares packs to support a variety of known and hypothetical operational scenarios. The modelled scenario will depend on whether the PEPs are independently funded or abated from main stock holding at the Main Operating Base (MOB). For the latter, both MOB and deployed operations must be modelled together to take account of the spares requirements of both sites, plus the pipelines between. This is currently being expanded to investigate the combined spares requirements of all aircraft involved in major operations and by evaluating against weight and volume, the total number of transport aircraft required for both initial deployment and continuing re-supply. Further studies are planned to investigate the long-term effects on home base flying and training.

## SUMMARY

The methods and working practices outlined above ensure that for introduction to service:

The combined skills and experience of both manufacturer and operator are used to carry out the development and LSA of new aircraft.

The use of common models and methods simplifies joint analysis and verification.

The maximum use is made of existing spares and support infrastructure, thus minimising the amount of analysis required and both initial and recurring costs.

Where there is no existing support for a system, LORA ensures the optimum MPoI is established.

Cost optimised scaling and operational simulation ensure the cost of IP spares is minimised to those necessary to achieve our designated operational requirements.

During the in-service phase:

LORA and spares analysis continues throughout the life of a system to maintain optimum capability at minimum cost.

Harmonisation of support for common items throughout the 3 Armed services achieves substantial cost savings.

CBA of proposed modifications and mid-life updates, highlights all financial implications and areas of risk of proposed modifications and prevents the wasting of money on non-viable cost saving schemes.

Sustainability modelling evaluates the minimum spares and transport requirements required to sustain known and hypothetical operations.

The use of a common user database with an integrated suite of models means that analysis can be carried out in very short time scales with a minimum of staff.